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Sedimentation Process of Rambatan Formation in Larangan Brebes, North Serayu Range, Central Java

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Abstract - Rambatan Formation in the western part of North Serayu Basin, Brebes, Central Java, comprises generally flysch facies of turbidite sediments deposited in a deep marine environment. This formation is equivalent to Merawu Formation found in the eastern part of the basin and deposited in the environment of tidal flat to subtidal. The turbidite sediments were highly controlled by a rapid downward movement taking place continuously during Early to Late Miocene. The variation of the depositional environment has been the object of this research which aims to understand the sedimentation process of Rambatan Formation in this type locality with a modern turbidite approach. Rambatan Formation was deposited in N13-N19, as a deep marine sediment channel, turbidite, and deep marine tidal zone. The sedimentation was affected by gravity flow and bottom current. The sediments on N13-N14 were marked by turbidite sediments until Middle N17. The sediment supply increased on Middle N17, as a sediment filler on a channel marked by contourite mud layer (muddy slump) and debris flow, with sources from the north. The increase of sediment supply was followed by an environmental transformation from a deep marine channel into deep marine tidal area. In N19, the sediments were redeposited as turbidite sediment, starting with debris flow in Middle N18.

Keywords: Rambatan Formation, deep marine channel, deep marine tidal, turbidite

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Introduction

The investigated area is located along Rambatan River, Pamulihan, Larangan Village, Brebes, Central Java, and the vicinity of Pamedaran and Kamal River (Figure 1). The research was focussed on the type locality of the northern part of Rambatan Formation composing of flysch and turbidite sediments deposited in a deep marine environment (Sujanto and Sumantri, 1977) as Bouma sequence. In the modern turbidite concept, Bouma sequence was not only formed by turbidite flow, but also by sandy debris flows and bottom-current reworking (Shanmugam, 1997). According to Shanmugam (2016, 2017), which was contourite analog with turbidites.

The turbidite sediment in general has high nutrient content (Hendrizan, 2016), potential as seal and source rock (Shanmugam, 2017). The source rock candidate is derived from the shale

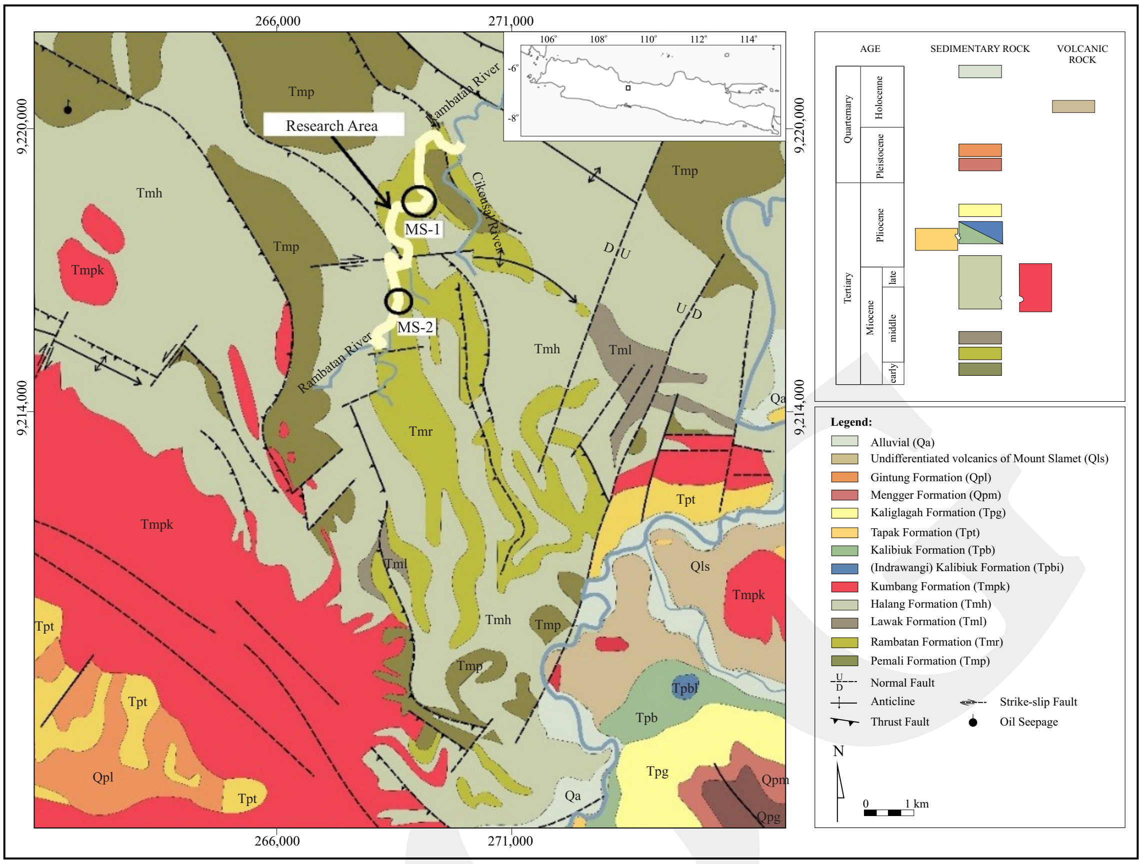

Figure 1. Regional map surrounding the researched area represented in white colour (source: Kastowo and Suwarna, 1996).

of Middle Miocene of Rambatan Formation (Prawiranegara *et al*., 2016).

From the slope to basin, the deep-marine environment (Shanmugam, 2003, 2010, 2016) associated with canyon, slide, slump, channel, levee, lobe, turbidity current, debris flow, sediment-gravity processes, contourite, pelagite, and hemipelagite. The complex of deep-water environments are dominated by mass-transport processes and bottom currents. The sediment found in deep marine environment is sand-mass transport deposits (SMTD), composed of sandy slides, sandy slumps, and sandy debris.

Submarine canyons provide unique setting for tidal processes to operate from shallow-marine to deep-marine environments. The deposits of deep-marine tidal currents were based on the presence of sand-mud rhythmites, double mud layers, climbing ripples, mud-draped ripples, alternation of parallel and cross-laminae, sigmoidal cross-bedding with mud drapes, internal erosional surfaces, lenticular bedding, and flasher bedding. Canyon-fill facies are characterized by the close association of sandy debris and tidalites. Some channels have distinct erosional bases, which cut into the underlying siltstones, in association with medium to coarse-grained sandstones with lateral-accretion surfaces and tractional structures which is common in channel-fill deposits (Abdurrokhim and Ito, 2013). The slump was motorized by gravitation and triggered by earthquake (Moretti and Sabato, 2007).

The turbidite sediments of North Serayu Basin were controlled by the rapid and continuous downward movement of the basin in the period of Early to Late Miocene (Koesoemadinata and Martodjojo, 1974). The tectonic activities of Mio-Pliocene and Pleistocene resulted in the syngenetic folding during the sedimentation in the Bogor Zone, North Serayu, and Kendeng. The term ellisional was appplied by Satyana and Asnidar (2008) producing the mud diapirs and mud volcanoes. The tectonic activity took place in Mio-Pliocene as indicated by the peak of volcanism represented by the formation of Kumbang volcanic rocks marked by the forming of Kumbang Volcano, and the change of North Serayu Basin into fore-arc basin (Bachri *et al*., 2011).

Rambatan Formation found in the western part of North Serayu Basin consists of sediments with the provenance associated with a magmatic arc. The lithic components in general decrease eastwardly toward the younger sediment (Astuti, 2015). The decreasing material supply in North Serayu Basin toward the younger age was interpreted as the decreasing volcanic activities. Based on the microstructure of the sediments (Astuti *et al*., 2017) and a fossil analysis, the sea level changed three times during Middle Miocene to Pliocene (Astuti, 2016).

Based on the biostratigraphic analysis carried out by Astuti *et al*. (2017), the lithology in Pamedaran area revealed the age of N14 to N20 and the hiatus in N15 (Early Upper Miocene).

Rambatan Formation in the western part of North Serayu Basin is equivalent to Merawu Formation located in the eastern part of the basin which generaly shows the different characters of sediments. Merawu Formation was deposited in the tidal flat to subtidal environment (Bachri, 2017; Martosuwito *et al*., 2018) as indicated by the presence of herring-bone and fossil tracks of *cruziana* (Bachri, 2017). The different lithological characteristic of Rambatan Formation from the turbidite deposits of deep sea to the tidal and subtidal environment, augmented by the geological condition since the tectonic acivities has drawn the interests for further evaluation.

Methodology

The active tectonics in the reserched area influenced the sedimentation process, both concerning the space accomodation, sediment supply, and sea level changes due to the tectonic activities. The tectonics influence the sedimentation process of Rambatan Formation was indicated by various features, such as synsedimentary structure, slump, and debris flow. To reveal the sedimentation process in the researched area, the detailed stratigraphic measurement was carried out. The measured stratigraphic section was accompanied by the collection of lithologic samples for paleontological and petrographical analyses. The sedimentation process was analyzed based on a modern turbidite concept referring to Shanmugam (2003, 2010, 2016).

The objective of petrographic analysis is to study the rock composition and texture. The paleontological analysis reveals the vertical succession of the rock age based on the fossil content or biostratigraphy (Isnaniawardhani, 2015). A paleontological analysis would discover the sedimentation environment (particularly indicates the depth). A detailed petrographic analysis would further show the rock components of Rambatan Formation. The paleocurrent observation was carried out to obtain the general direction of the sedimentation.

The stratigraphic measurement to find out the rock succession from old to young, was based on the lithology, sedimentary structure, grain size, and a thickness analysis. In Rambatan River the measurement was carried out in Pamedaran (MS-1) and Kamal-1 (MS-2) which represented the north-south lithologic distribution. The stratigraphic measurents of those places were 215,5 and 195 m respectively.

Results and Analysis

Lithology

The lithology was dominated by the intercalation of calcareous sandstone and calcareous claystone (SC), grain flow, slump, and mud clast (Figure 2). According to Li *et al.* (2017) the mud clast can be categorized as a failure of muddy banks and transportation in the channel and the failure of muddy base and transportation of debris flows. The intercalation of calcareous sandstone and calcareous claystone which was dominated by sedimentary structures such as graded bedding, parallel lamination (Figure 2a), and convolute. The grain flow had a variation of fragment size,

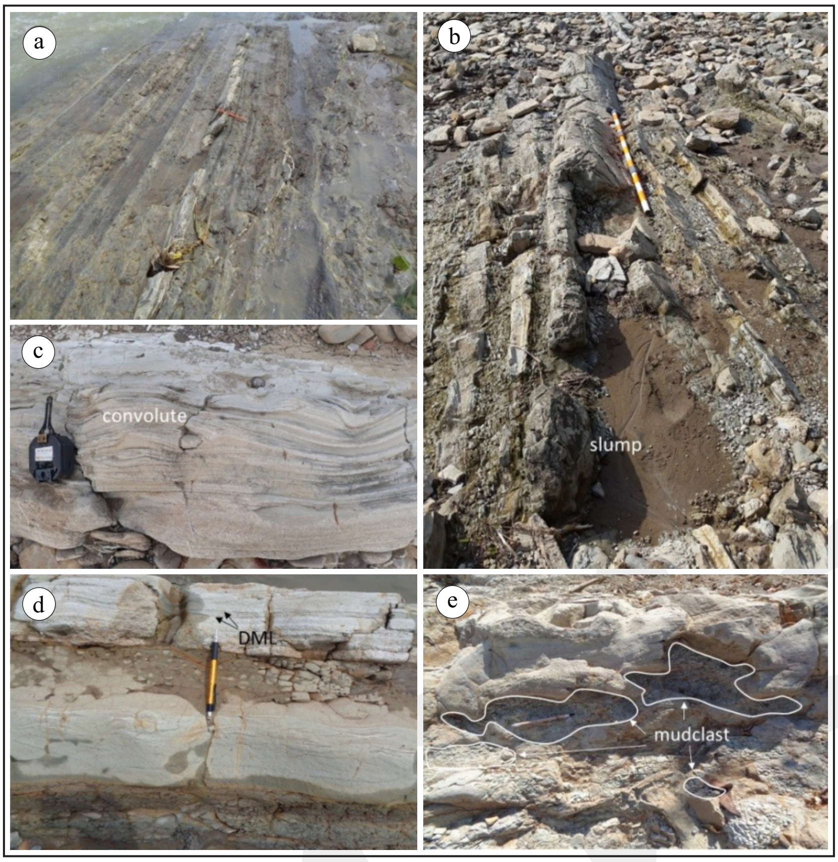

Figure 2. Field photo of Rambatan Formation. a) intercalated of calcareous sandstone and calcareous claystone; b) contoured mud layer (muddy slump); c) double mud layer (MDL); d) mud clast.

starting from pebble to cobble, in the form of igneous rock fragments and sediment. The thickness of the slump is about 23 m as shown in MS-1.

The results of the petrography analysis show the indication of carbonate (Figure 3). The carbonate decreased (Figure 3c), especially in the association with mud clast followed by lithic fragments and plagioclase, increasing of about 65%. The peak of the carbonate is found in the top of the sediments, with fossil content increases to about 57%.

Biostratigraphy

The detailed biostratigraphic analysis (Figure 4) with an interval approach, both in Pamedaran and Kamal-1, shows the appearance of index fossils of *Globigerinoides extremus, Globorotalia plesiotumida, Globorotalia pseudomiocenica, Globorotalia miocenica, Globorotalia mayeri, Globigerina venezuelana, Globigerina riveroae, Sphaeroadinella dehiscens,* and *Sphaeroidinella subdehiscens*.

The presence of *Globorotalia miocenica* is associated with debris flow and contourite mud layer (mud slump) which ended up with double mud layers (DML). The end of *Globigerina riveroae* presence is associated with mud clast and the decrease of carbonate and the increase of noncarbonate mineral in the form of lithic fragments and plagioclase. The occurence of *Sphaeroidinella subdehiscens* associated with the climax of carbonate is dominated by small foraminifera fossil contents.

Environmental

Identifications of sedimentation environment in general were based on benthic foraminifera, trace fossils, and sedimentary structures. According to Li *et al*. (2017), a sedimentary environment could be identified by the presence of mud clast.

Trace fossil consisting of *Planolites* indicates the track of sediment eaters that show an environment of shallow to deep water (Figure 5).

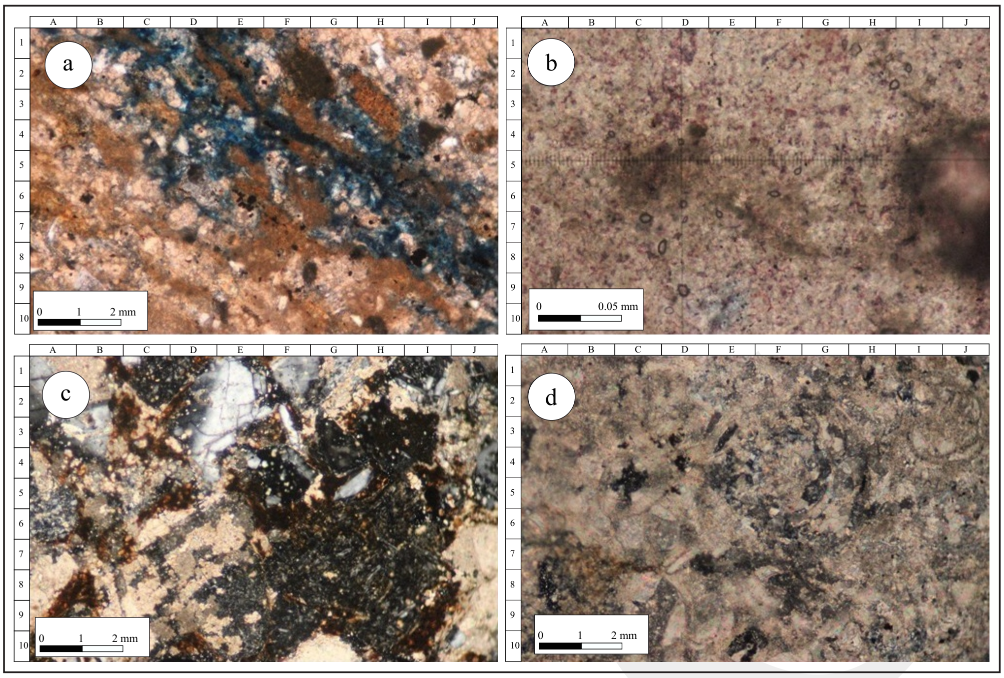

Figure 3. Samples of a). muddy micrite (P-1); b). mudstone (P-2); c) micritic sandstone (P-3); d). wackestone (P-4).

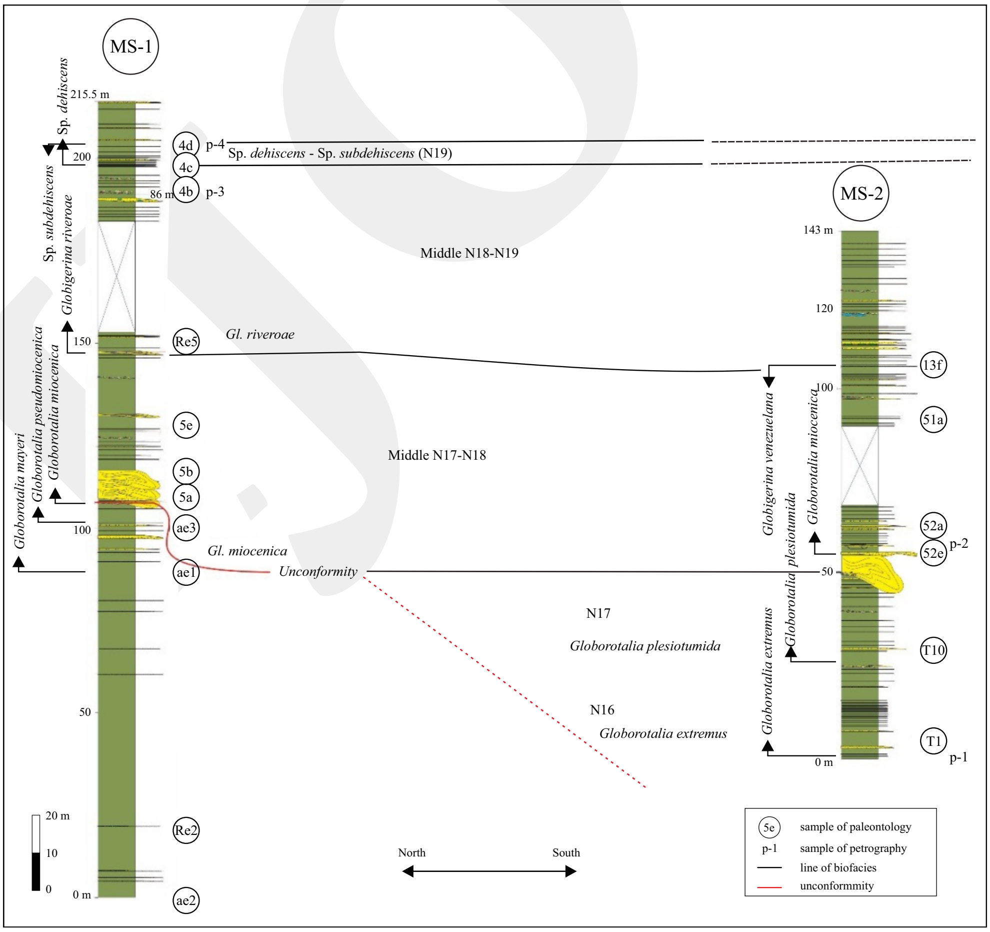

Figure 4. Stratigraphic coloumn based on detailed measurements in Pamedaran and Kamal-1, and the biostratigraphic succession based on a fossil analysis and the age Blow number.

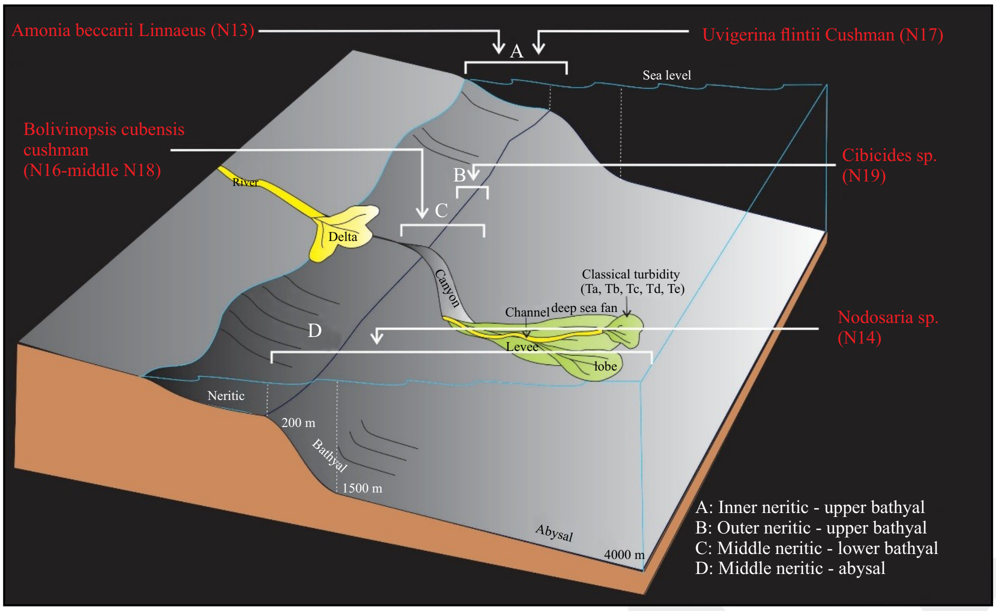

Figure 5. The depositional environment model of Rambatan Formation based on benthonic foraminifera.

Generally, benthic foraminifera in the researched area shows a middle neritic to lower bathyal environment (Figure 5). Mud clast with poorly rounded and sorted, low textural maturity was deposited as a debris flow by gravity flows in a deep water environment (Figure 2d and Table 1). According to Shanmugam (2016), a sandy debris flow deposit indicates a plastic debris flow. The presence of muddy base in grain flow reveals a deep marine channel. The presence of double mud layer (DML) indicates a deep marine tidal zone.

Paleocurrent

Identification of paleocurrents were based on elongation of fragments in the grain flow and sedimentary structure which shows the direction of the current is west to east in N16 to Early N17 (Table 2 and Figure 6a). In Middle N17 to Middle N18, the flow direction is indicated by the grain rock fragments (Tables 3 and 4; Figures 6b and c), and slump showing directions from the north to the south (Table 5; Figure 6d).

Discussion

The sediment pattern before the hiatus demonstrated the feature of coarsening upward which is interpreted as a regressive sea level (Figure 7). On the other hand, the sediment pattern above the hiatus, in particular with the presence of *Globorotalia miocenica* and the lithologic character, became finning upward trangressive sea lavel (Figure 6).

Regionally, the lithology of Rambatan Formation shows the characteristic of a deep sea environment. However, in the researched area, this formation shows the evidence of the range of environment from a relatively middle neritic

Table 1. Identification of Environment Based on the Association of Lithology

Characteristic	Associated	Interpretation
Sand-clay	SC, graded bedding, ripple, parallel lamination	Deep marine
Muddy Slump	Folded Sediment, SC	Channel fill deep water
Debris flow	Grain flow with muddy base, micro slump, SC	Channel fill deep water
DML	SC, double mud leyer	Tidal deep water
Debris flow	Mud clast with poorly rounded and sorted, low textural maturity; SC	Deep water

Table 2. Measurement of ripple mark at MS-2

NO	(N…°E)		NOTATION	∑	%
1	10-20	190-200	II	2	2.9
2	30-40	210-220	II	2	2.9
3	40-50	220-230	III	3	4.3
4	50-60	230-240	IIIII IIIII IIIII IIIII II	22	17.1
5	60-70	240-250	IIIII IIIII IIIII I	16	22.9
6	70-80	250-260	IIIII IIIII IIIII IIIII IIIII I	26	37.1
7	80-90	260-270	IIIII III	8	11.4
8	110-120	290-300	I	1	1.4
		TOTAL		80	100

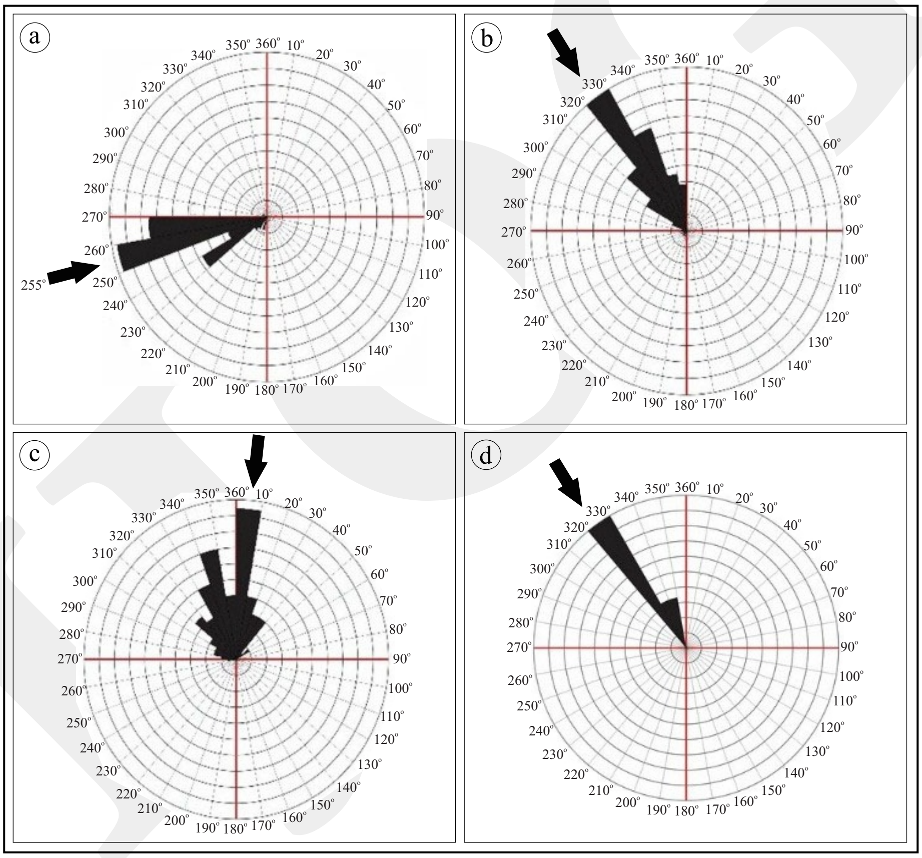

Figure 6. Rosette diagram of a). ripples; b). fragment of grain flow at MS-1; c). fragment of grain flow at MS-2; d). slump at MS-1, showing paleocurrent directions.

to deep marine as indicated by the presence of benthic and trace fossils. The benthic small formanifera analyis in the collected samples tends to indicate the depositional environment was between neritic to bathyal (Figure 5).

The lithological association demonstrated the existence of huge rock sliding after the hiatus namely at the age of N17 as indicated by the first appearance of *Globorotalia miocenica.* Maximum supply sediment happened in Middle N17 as marked by the presence of debris flow and contoured mud layer (muddy slump) (Figure 2) as the filler of a deep marine channel (Table 1 and Figure 6).

Table 3. Measurement of fragment at MS-1

NO	(N…°E)		NOTATION	∑	%
1	10 - 20	190 - 200	I	1	1
2	30 - 40	210 - 220	I	1	1
3	40 - 50	220 - 230	I	1	1
4	60 - 70	240 - 250	I	1	1
5	80 - 90	260 - 270	I	1	1
6	90 - 100	270 - 280	I	1	1
7	110 - 120	290 - 300	III	3	3
8	120 - 130	300 - 310	IIIII III	8	8
9	130 - 140	310 - 320	IIIII IIIII IIIII	15	15
10	140 - 150	320 - 330	IIIII IIIII IIIII IIIII IIIII IIIII	30	30
11	150 - 160	330 - 340	IIIII IIIII IIIII IIIII	20	20
12	160 - 170	340 - 350	IIIII IIIII I	11	11
13	170 - 180	350 - 360	IIIII II	7	7
		TOTAL		100	100

Table 4. Measurement of fragment at MS-2

NO	(N…°E)		NOTATION	∑	%
1	0 - 10	180 - 190	IIIII IIIII IIIII IIII	19	19
2	10 - 20	190 - 200	IIIII III	8	8
3	20 - 30	200 - 210	IIIII I	6	6
4	30 - 40	210 - 220	IIIII I	6	6
5	40 - 50	220 - 230	I	1	1
6	50 - 60	230 - 240	II	2	2
7	80 - 90	260 - 270	I	1	1
8	90 - 100	270 - 280	II	2	2
9	100 - 110	280 - 290	III	3	3
10	110 - 120	290 - 300	III	3	3
11	120 - 130	300 - 310	IIII	4	4
12	130 - 140	310 - 320	IIIII II	7	7
13	140 - 150	320 - 330	IIIII I	6	6
14	150 - 160	330 - 340	IIIII IIIII	10	10
15	160 - 170	340 - 350	IIIII IIIII IIII	14	14
16	170 - 180	350 - 360	IIIII III	8	8
		TOTAL		100	100

Table 5. Measurement of slump at MS-1

NO	(N…°E)		NOTATION	∑	%
1	140 - 150	320 - 330	III	3	60
2	150 - 160	330 - 340	I	1	20
3	160 - 170	340 - 350	I	1	20
		TOTAL		5	100

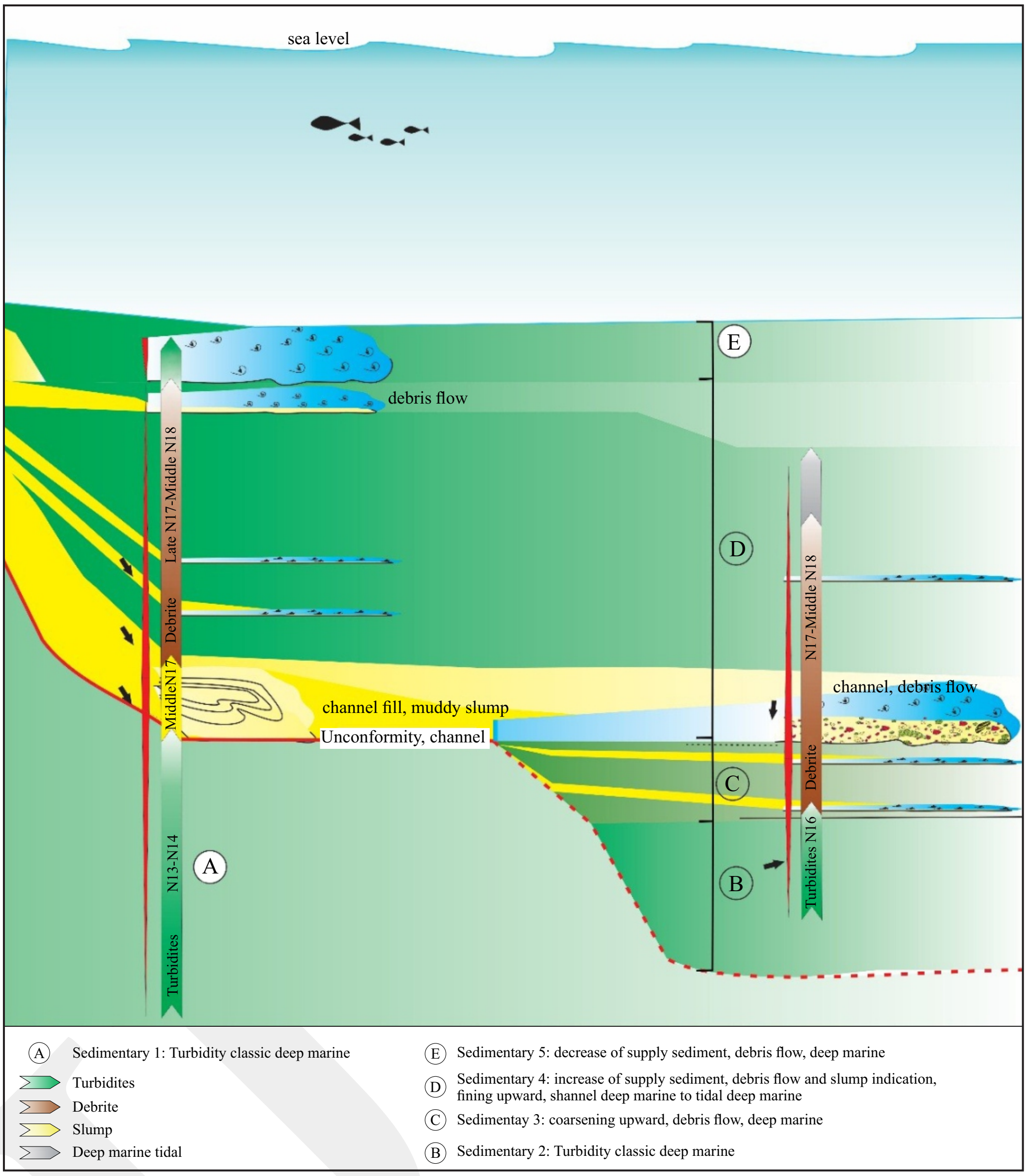

Figure 7. Illustration environment change of Rambatan Formation.

Conclusions

The sedimentary process of Rambatan Formation took place writhin a deep-marine environment, especially within a deep marine channel and deep marine tidal in N13 to N19. The sedimentation was affected by gravity flow and bottom current. The Middle N17 was an important phase of the formation of Rambatan as the peak of sedimentation, with the sources from the north. The increase of sediment supply was associated with contourite mud layer (muddy slump) and debris flow. The increase of the supply was followed by the environmental change of a deep marine channel to a deep marine tidal zone.

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